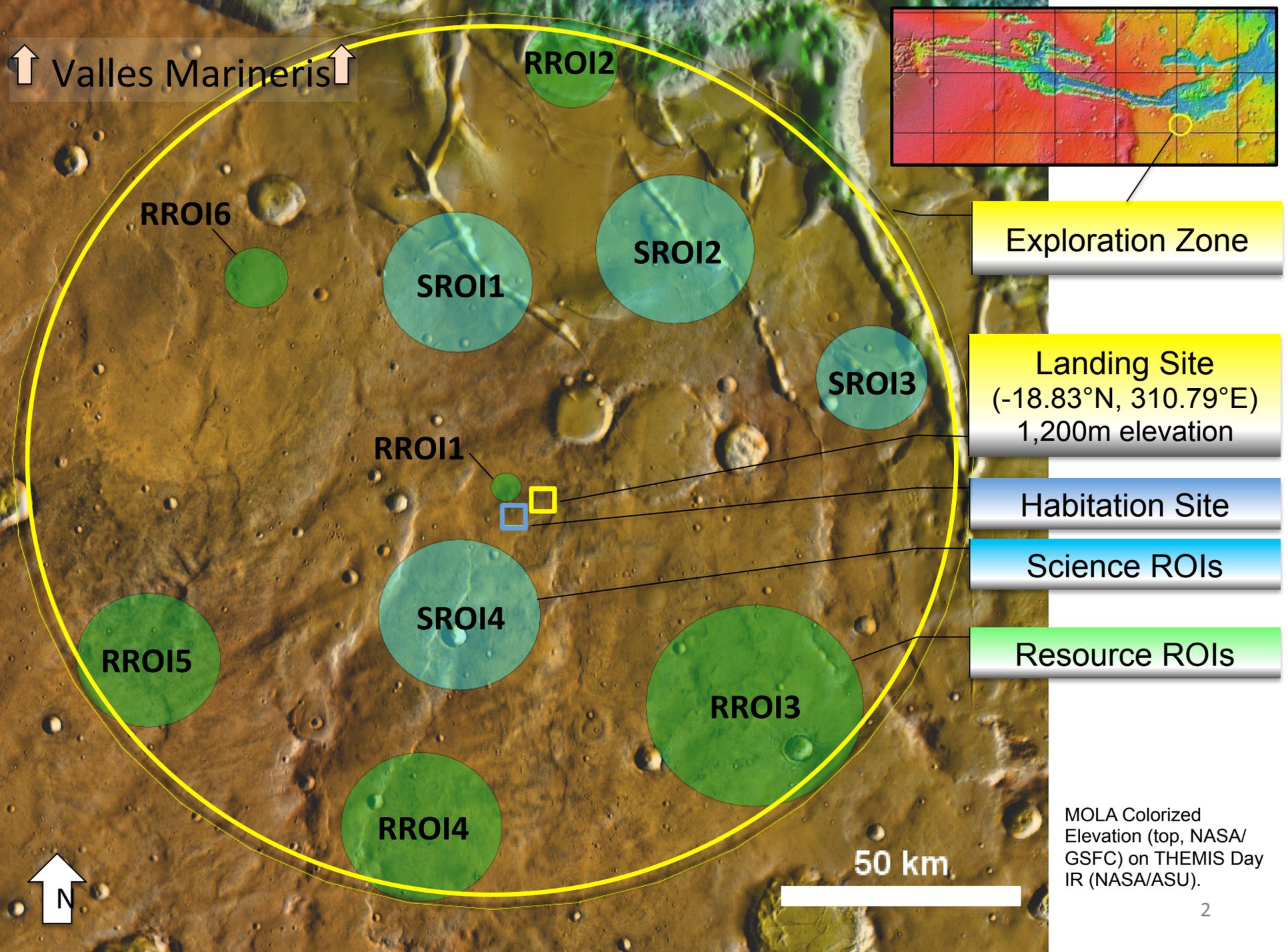


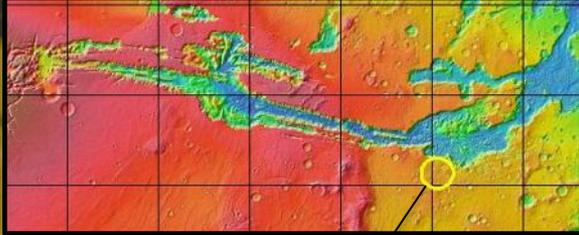
Equatorial Opportunities for Humans on Mars

#1023

Julie Mitchell* (Julie.L.Mitchell@asu.edu)
Philip Christensen
Arizona State University



↑ Valles Marineris ↑



Exploration Zone

Landing Site
(-18.83°N, 310.79°E)
1,200m elevation

Habitation Site

Science ROIs

Resource ROIs

RROI6

RROI2

SROI1

SROI2

SROI3

RROI1

SROI4

RROI5

RROI3

RROI4

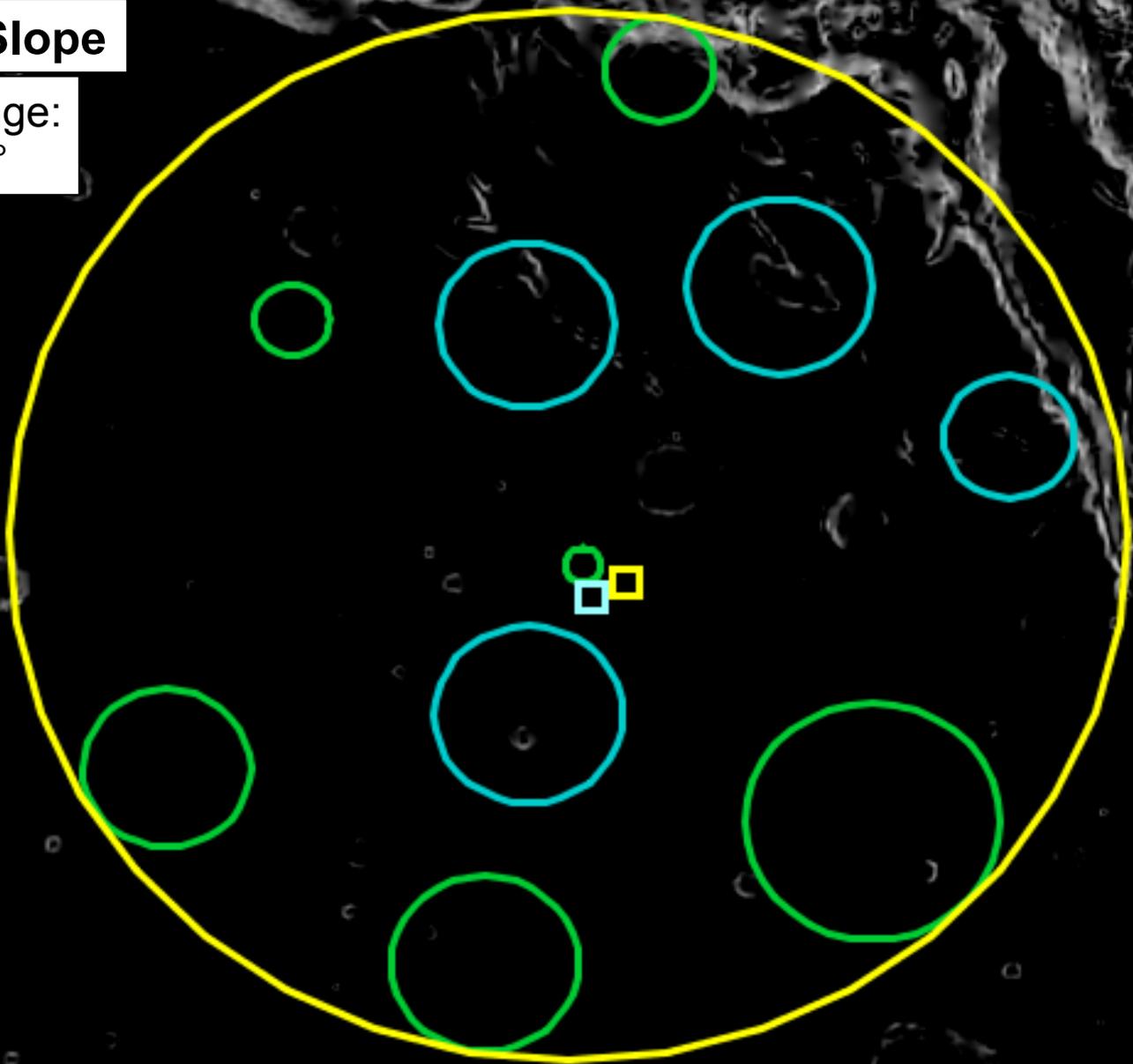
50 km



MOLA Colorized
Elevation (top, NASA/
GSFC) on THEMIS Day
IR (NASA/ASU).

MOLA EZ Slope

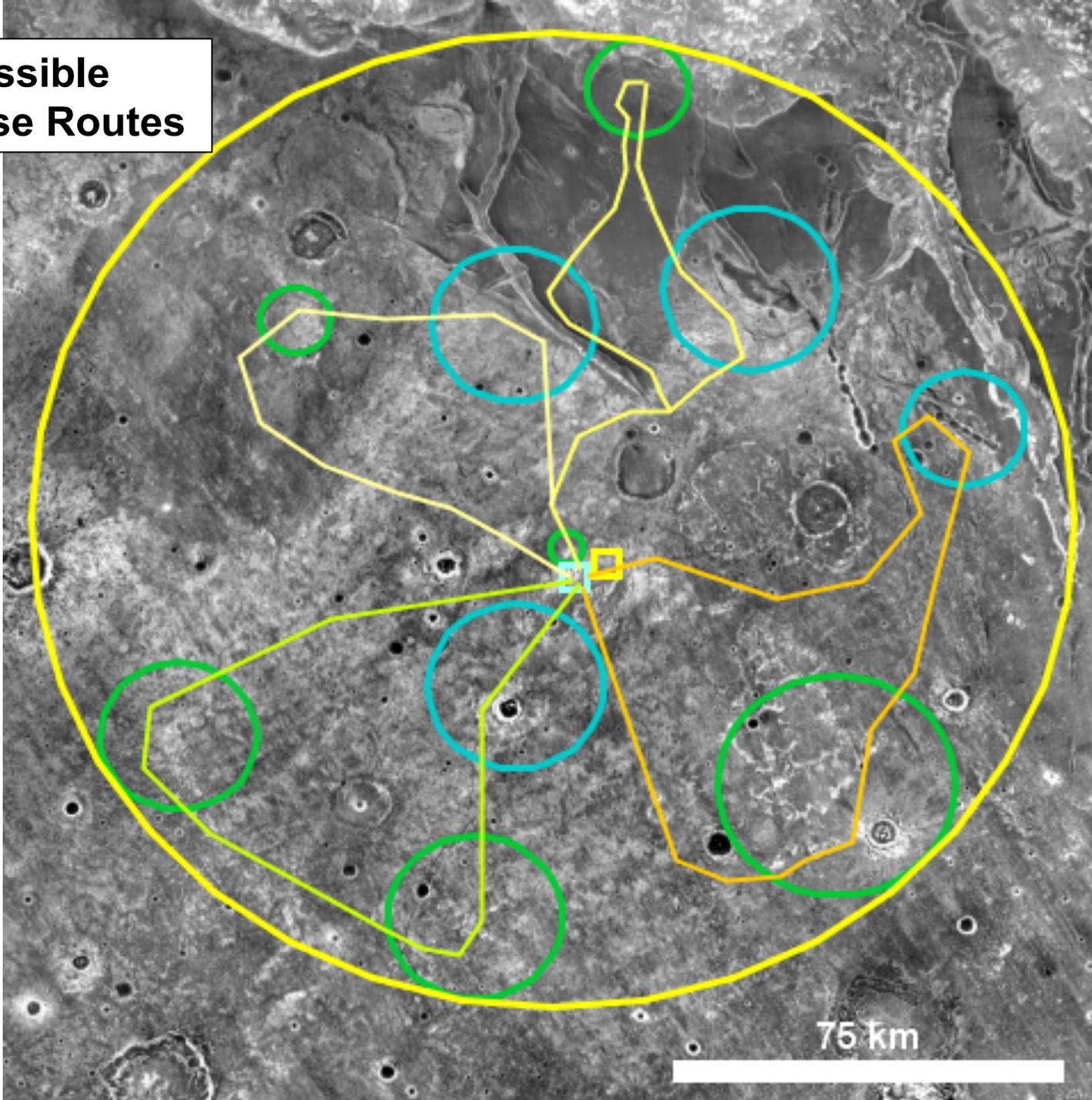
Slope Range:
10° - 40°



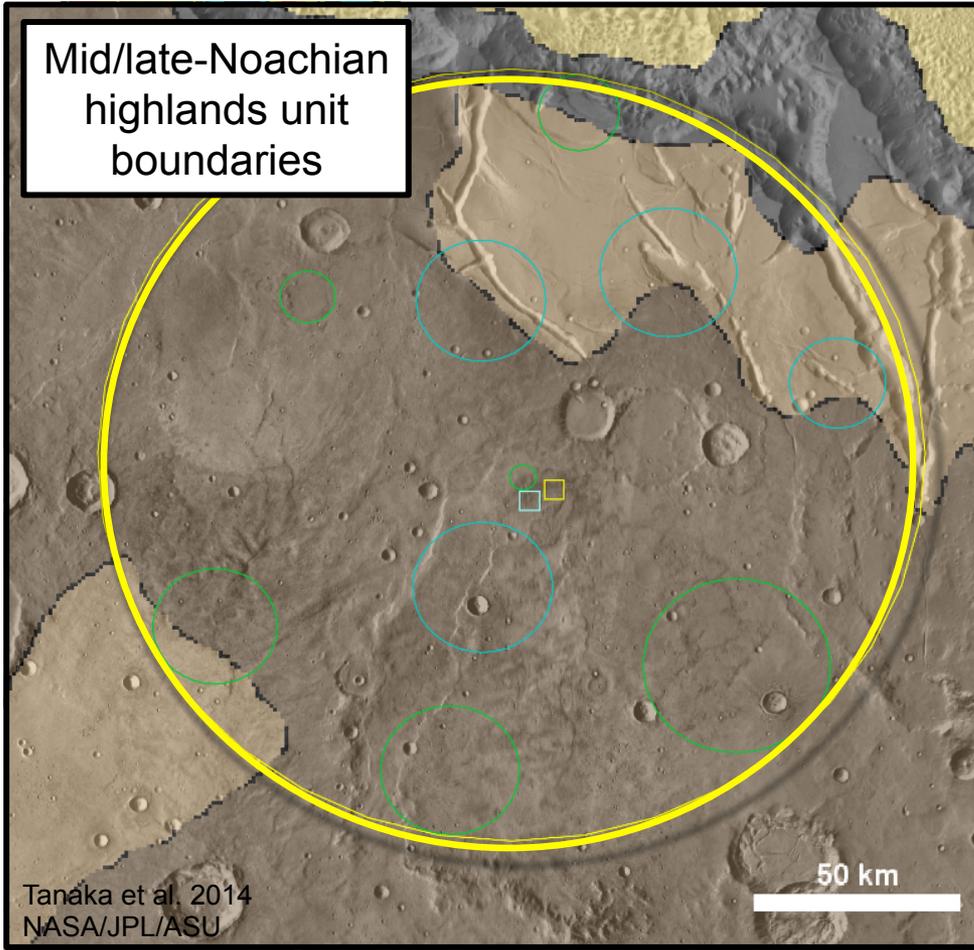
75 km



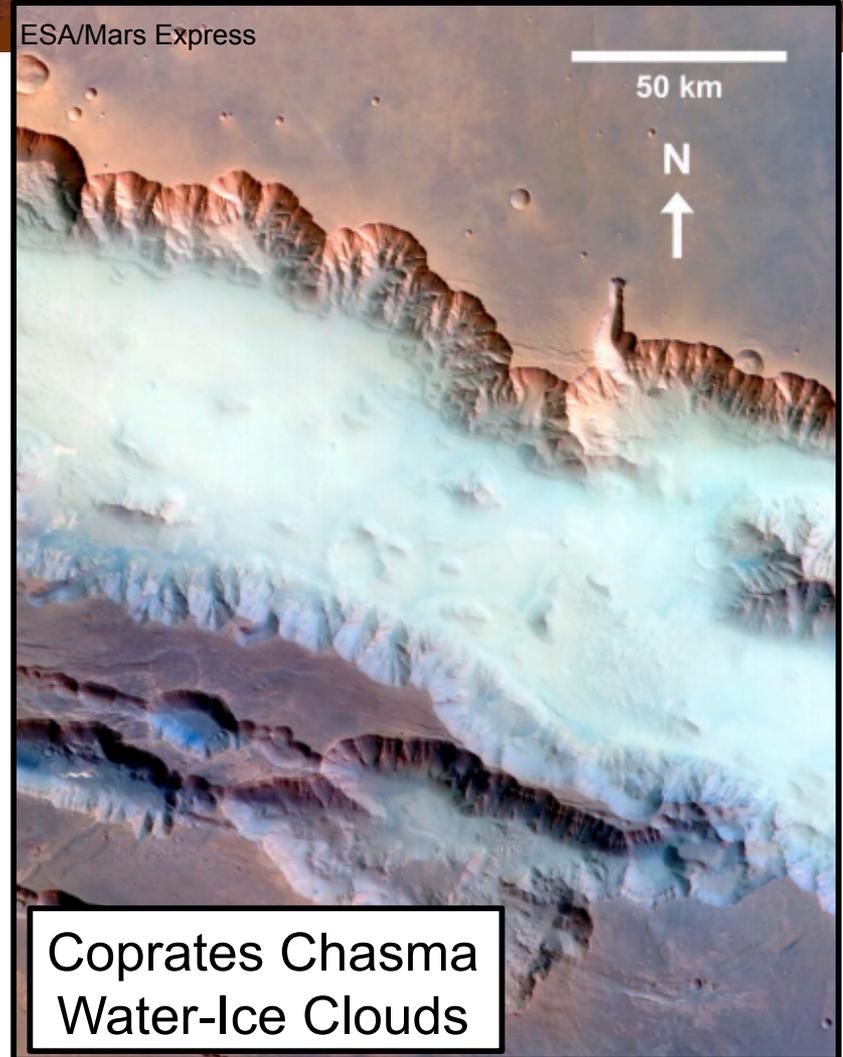
Possible Traverse Routes



EZ-Wide Science & Resources



Tanaka et al. 2014
NASA/JPL/ASU
Connerney et al. (2005)



RUBRICS



Science ROIs Rubric

1st EZ Workshop for Human Missions to Mars



| Site Factors | | | SROI1 | SROI2 | SROI3 | SROI4 | RROI1 | RROI2 | RROI3 | RROI4 | RROI5 | RROI6 | EZ SUM |
|---------------------|------------|---|---------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|
| Astrobio | Threshold | AND/OR | Potential for past habitability | | | | | | | | | | 7,0 |
| | | Potential for present habitability/refugia | | | | | | | | | | 0,3 | |
| Astrobio | Qualifying | Potential for organic matter, w/ surface exposure | | | | | | | | | | 0,0 | |
| Atmospheric Science | Threshold | Noachian/Hesperian rocks w/ trapped atmospheric gases | | | | | | | | | | 0,0 | |
| | Qualifying | Meteorological diversity in space and time | | | | | | | | | | 10,0 | |
| | | High likelihood of surface-atmosphere exchange | | | | | | | | | | 3,0 | |
| | | Amazonian subsurface or high-latitude ice or sediment | | | | | | | | | | 0,0 | |
| | | High likelihood of active trace gas sources | | | | | | | | | | 0,0 | |
| Geoscience | Threshold | Range of martian geologic time; datable surfaces | | | | | | | | | | 4,0 | |
| | | Evidence of aqueous processes | | | | | | | | | | 7,2 | |
| | | Potential for interpreting relative ages | | | | | | | | | | 4,0 | |
| | Qualifying | Igneous Rocks tied to 1+ provinces or different times | | | | | | | | | | 4,0 | |
| | | Near-surface ice, glacial or permafrost | | | | | | | | | | 0,0 | |
| | | Noachian or pre-Noachian bedrock units | | | | | | | | | | 9,0 | |
| | | Outcrops with remnant magnetization | | | | | | | | | | 9,0 | |
| | | Primary, secondary, and basin-forming impact deposits | | | | | | | | | | 0,0 | |
| | | Structural features with regional or global context | | | | | | | | | | 6,0 | |
| | | Diversity of aeolian sediments and/or landforms | | | | | | | | | | 10,0 | |

| Key | |
|-----|----------------------------|
| ● | Yes |
| ○ | Partial Support or Debated |
| | No |
| ? | Indeterminate |

Resource ROIs Rubric

1st EZ Workshop for Human Missions to Mars

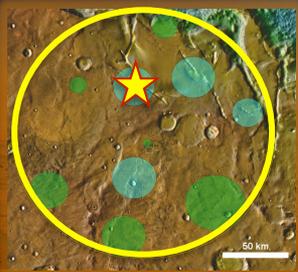


| | | Site Factors | SROI1 | SROI2 | SROI3 | SROI4 | RROI1 | RROI2 | RROI3 | RROI4 | RROI5 | RROI6 | EZ SUM | | |
|--|---|---|--|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|-------|--------|
| ISRU and Civil Engineering Criteria | Engineering | Meets First Order Criteria (Latitude, Elevation, Thermal Inertia) | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | (10,0) | | |
| | Water Resource | Threshold | AND/OR Potential for ice or ice/regolith mix | | | | | | | | | | | (0,0) | |
| | | | Potential for hydrated minerals | ● | ● | ● | | ● | ○ | ● | ● | ● | | (7,1) | |
| | | | Quantity for substantial production | | | | | ● | | | ● | | | | (2,0) |
| | | | Potential to be minable by highly automated systems | ● | ● | ● | | ● | ● | ● | ● | ● | | | (8,0) |
| | | | Located less than 3 km from processing equipment site | | | | | ● | | | | | | | (1,0) |
| | | | Located no more than 3 meters below the surface | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | (6,0) |
| | | | Accessible by automated systems | ● | ● | ● | | ○ | ● | ● | ● | ● | ● | | (7,1) |
| | Qualifying | Qualifying | Potential for multiple sources of ice, ice/regolith mix and hydrated minerals | | | | | | | | | | | (0,0) | |
| | | | Distance to resource location can be >5 km | ● | ● | ● | | | ● | ● | ● | ● | | | (7,0) |
| | | | Route to resource location must be (plausibly) traversable | ● | ● | ● | | | ● | ● | ● | ● | ● | | (8,0) |
| | Civil Engineering | Threshold | ~50 sq km region of flat and stable terrain with sparse rock distribution | | | | ● | ● | | ● | ● | ● | ● | (6,0) | |
| | | | 1-10 km length scale: <10° | ○ | ○ | ○ | ○ | ● | | ● | ● | ● | ● | (5,4) | |
| | | | Located within 5 km of landing site location | | | | | ● | | | | | | | (1,0) |
| | Qualifying | Qualifying | Located in the northern hemisphere | | | | | | | | | | | (0,0) | |
| | | | Evidence of abundant cobble sized or smaller rocks and bulk, loose regolith | | | | | ○ | | | | ○ | ○ | | (0,3) |
| | Food Production | Qualifying | Utilitarian terrain features | ● | ● | ● | ● | | ● | | | | | (5,0) | |
| | | | Low latitude | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | | (10,0) |
| | | | No local terrain feature(s) that could shadow light collection facilities | | | | ● | ● | | ● | ● | ● | ● | | (6,0) |
| | | | Access to water | ● | ● | ● | | ● | ○ | ● | ● | ● | | | (7,1) |
| Metal/Silicon Resource | Threshold | Access to dark, minimally altered basaltic sands | | | | | | | | | | ● | (1,0) | | |
| | | Potential for metal/silicon | | | | ● | ● | | ● | | ● | ● | ● | (4,0) | |
| | | Potential to be minable by highly automated systems | | | | ● | ● | | ● | | ● | ● | ● | (4,0) | |
| | | Located less than 3 km from processing equipment site | | | | | ● | | | | ● | ● | ● | (0,0) | |
| | Located no more than 3 meters below the surface | | | | ● | ● | | ● | | ● | ● | ● | (4,0) | | |
| | Accessible by automated systems | | | | ● | ● | | ● | | ● | ● | ● | (4,0) | | |
| | Qualifying | Qualifying | Potential for multiple sources of metals/silicon | | | | ● | | ● | | ● | ● | ● | (1,0) | |
| Distance to resource location can be >5 km | | | | | | ● | ● | | ● | | ● | ● | ● | (4,0) | |
| Route to resource location must be (plausibly) traversable | | | | | | ● | ● | | ● | | ● | ● | ● | (4,0) | |

| Key | |
|-----|----------------------------|
| ● | Yes |
| ○ | Partial Support or Debated |
| | No |
| ? | Indet. |

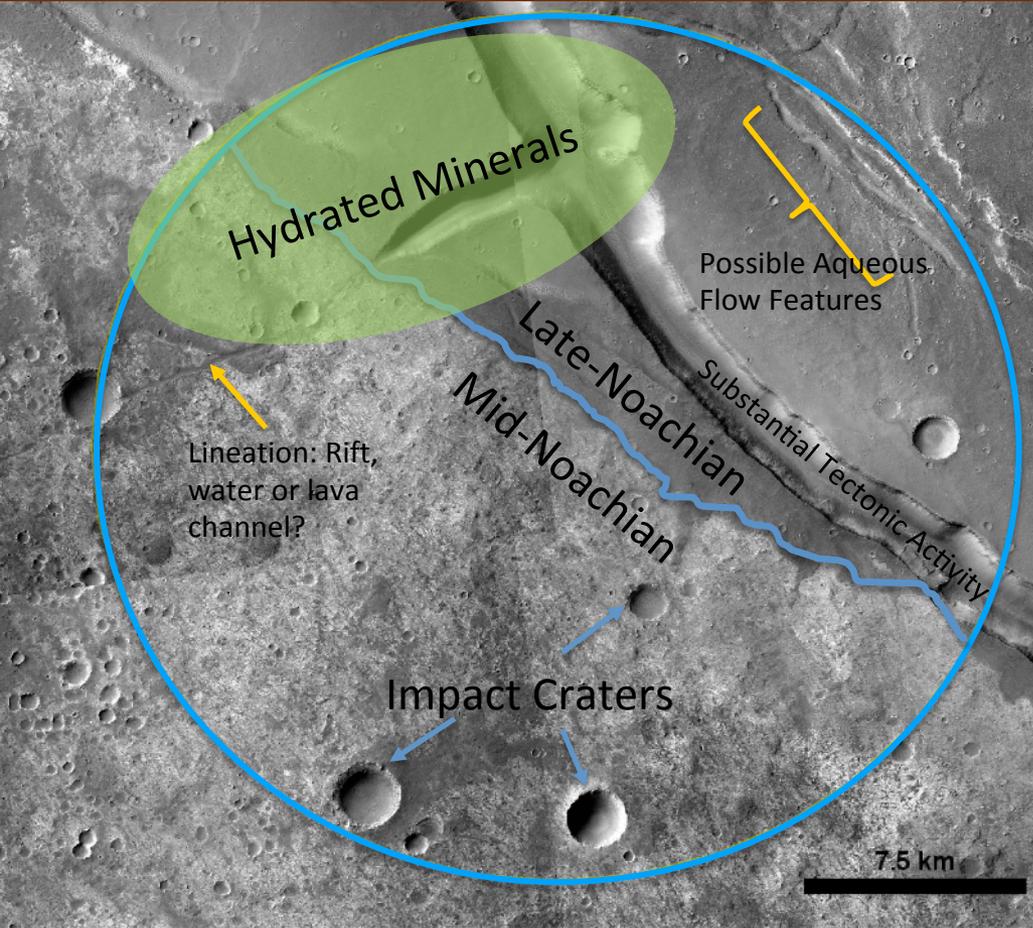
An astronaut in a white spacesuit stands on the reddish, rocky surface of Mars, looking out over a vast, flat landscape under a clear blue sky. A bright sun is visible on the horizon to the left. The astronaut is wearing a helmet and a backpack, and is standing with their back to the camera, looking towards the horizon.

SCIENCE ROI_s



Science ROI 1

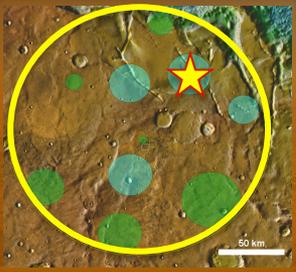
1st EZ Workshop for Human Missions to Mars



Coordinates: (-18.00°N, 310.48°E)
Elevation: 1,200m

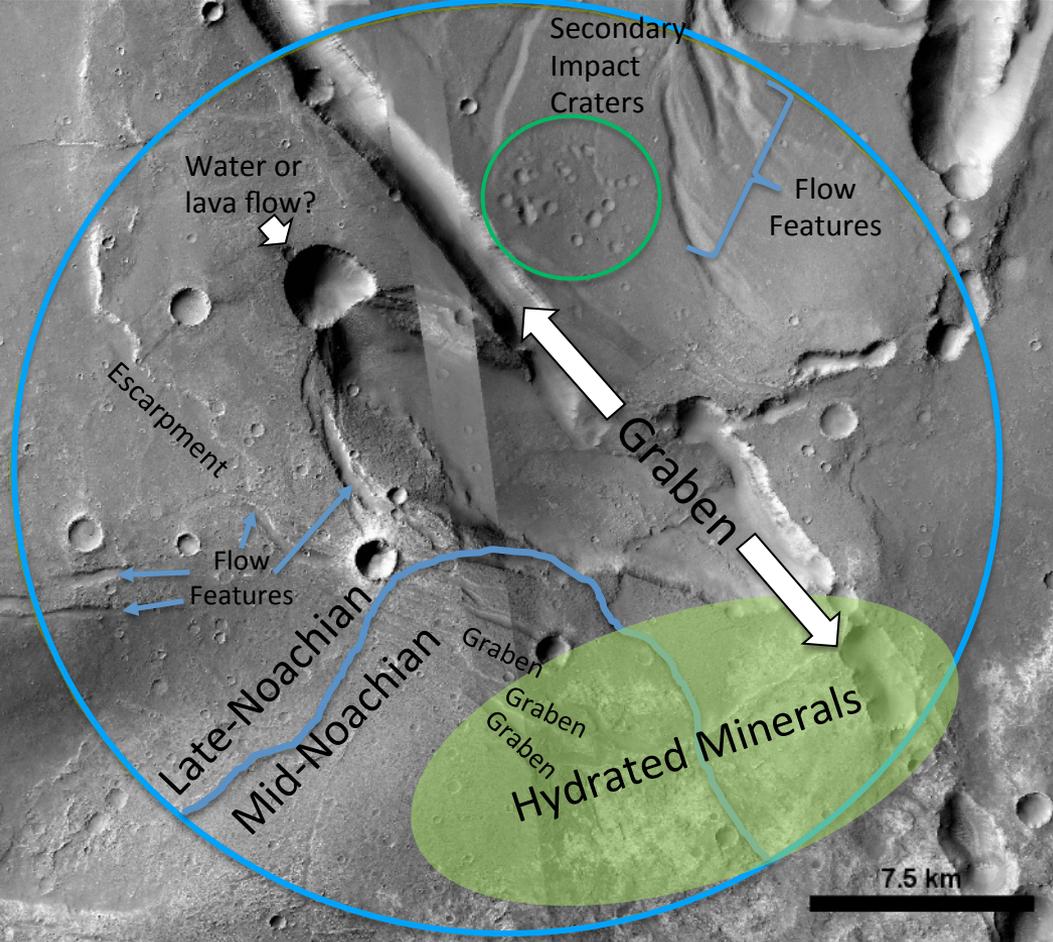
- Coverage:
 - Full CTX
 - Partial HRSC/CRISM
 - No HiRISE
- Primary Science Opportunities:
 - mNh/INh contact
 - Hydrated minerals
 - Study of global tectonic process (VM formation)
 - Aqueous geomorphology
 - Impact crater processes

CTX basemap (NASA/JPL-Caltech/MSSS). Hydrated minerals from OMEGA (ESA/CNES/CNRS/IAS/ Université Paris-Sud, Orsay). Geologic contact from Tanaka et al., 2015.



Science ROI 2

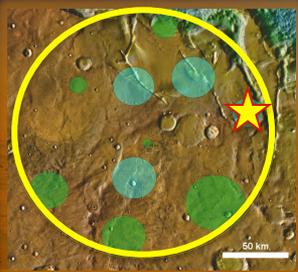
1st EZ Workshop for Human Missions to Mars



Coordinates: (-17.87°N, 311.29°E)
Elevation: 650m

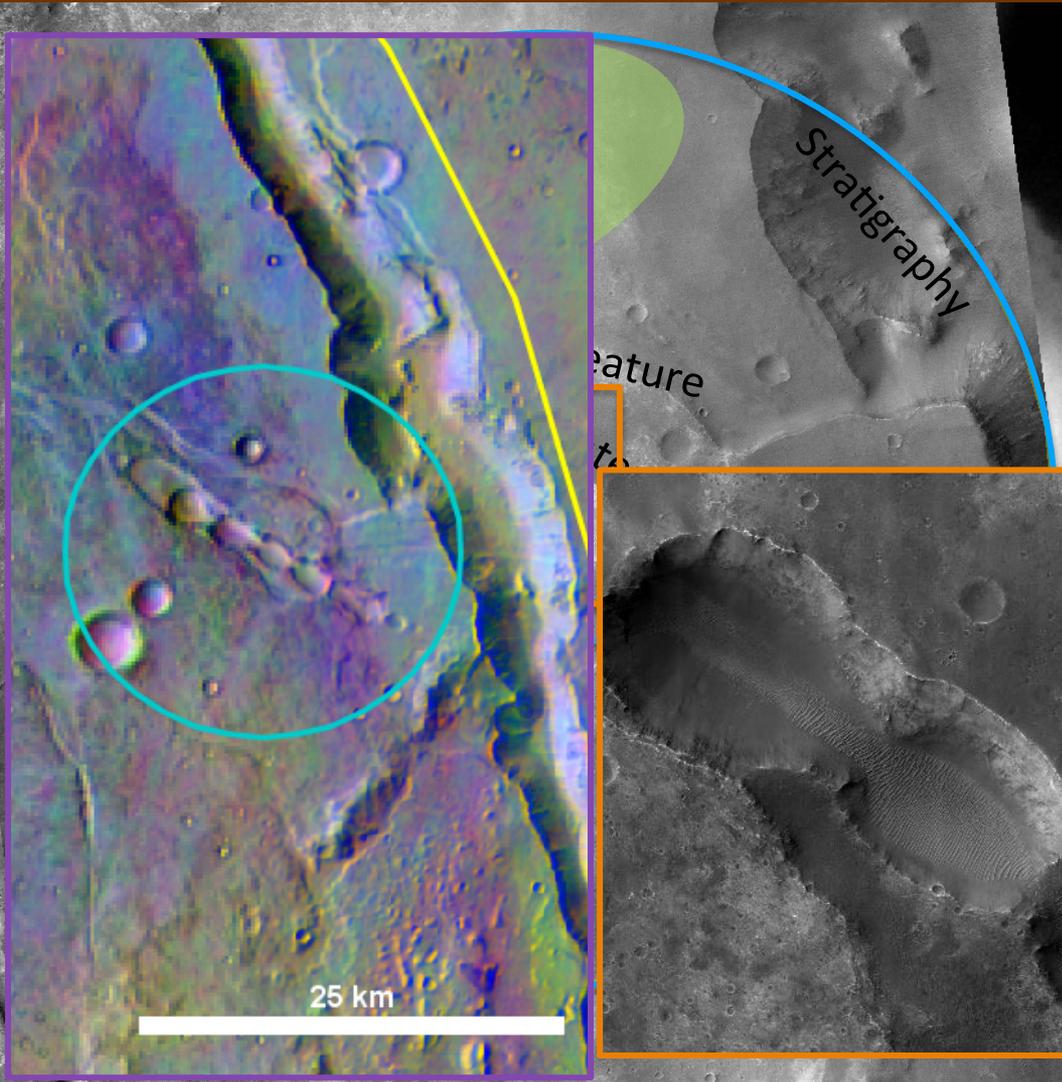
- Coverage:
 - Full CTX
 - Partial HRSC/HiRISE
 - No CRISM
- Primary Science Opportunities:
 - Eruption event in NW quadrant
 - Study of global tectonic process (VM formation)
 - Impact crater processes, including possible secondaries
 - Aqueous geomorphology
 - mNh/INh contact
 - Hydrated minerals

CTX basemap (NASA/JPL-Caltech/MSSS). Hydrated minerals from OMEGA (ESA/CNES/CNRS/IAS/ Université Paris-Sud, Orsay). Geologic contact from Tanaka et al., 2015.



Science ROI 3

1st EZ Workshop for Human Missions to Mars



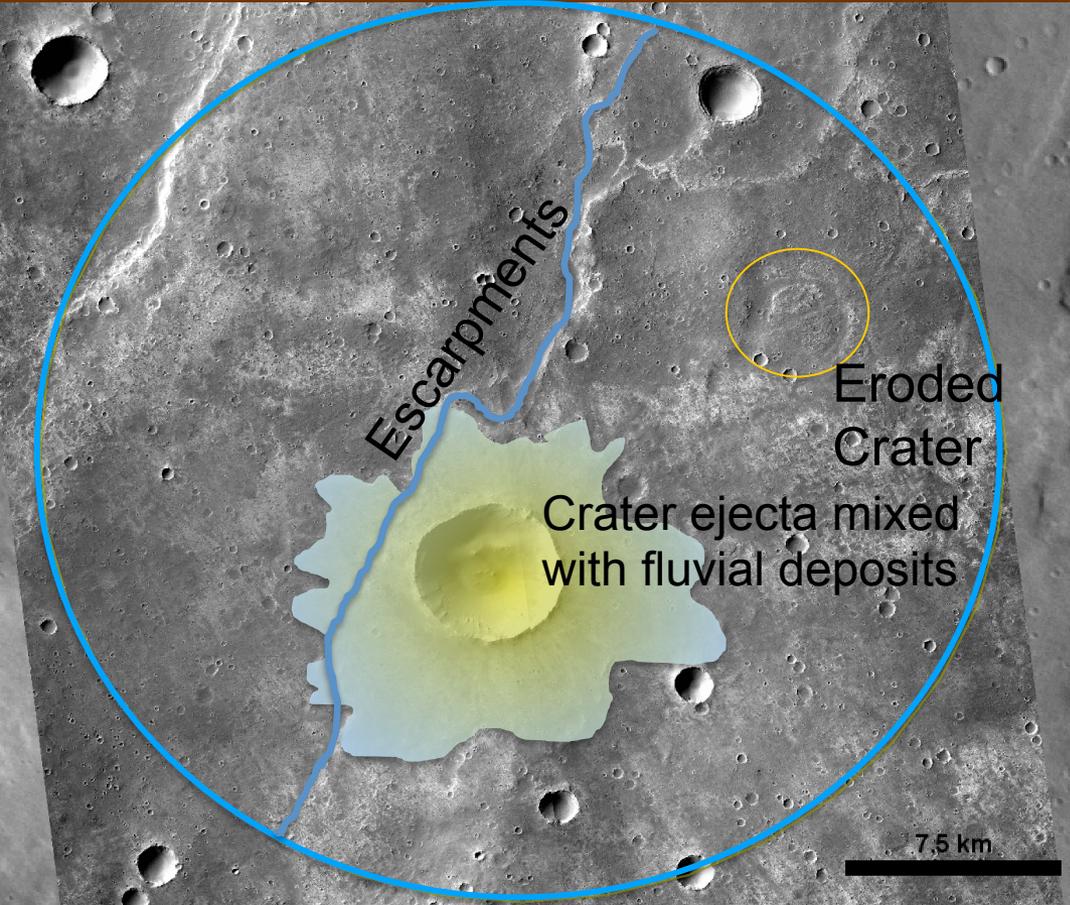
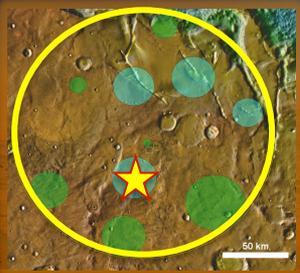
Coordinates: (-18.34°N, 312.01°E)
Elevation: 1,180m

- Coverage:
 - Full CTX
 - Partial HRSC/CRISM/ HiRISE
- Science Opportunities:
 - Pit crater chain: volcanic or tectonic process?
 - Olivine deposits
 - Tharsis stratigraphy
 - Flow features in INh unit
 - INh/mNh unit transition
 - Hydrated minerals
 - Impact crater processes

CTX basemap (NASA/JPL-Caltech/MSSS). Hydrated mins - OMEGA (ESA/CNES/CNRS/IAS/Université Paris-Sud, Orsay). Geologic units - Tanaka et al., 2015. Olivine - THEMIS DCS/ Edwards et al., 2008). Pit chain hi-res- HiRISE (NASA/JPL/UA).

Science ROI 4

1st EZ Workshop for Human Missions to Mars



Coordinates: (-19.23°N, 310.49°E)
Elevation: 1,365m

- Coverage:
 - Full CTX/HRSC
 - Partial CRISM
 - No HiRISE
- Science Opportunities:
 - Numerous escarpments: indicative of compressional tectonics
 - Rampart crater: ancient fluvial processes

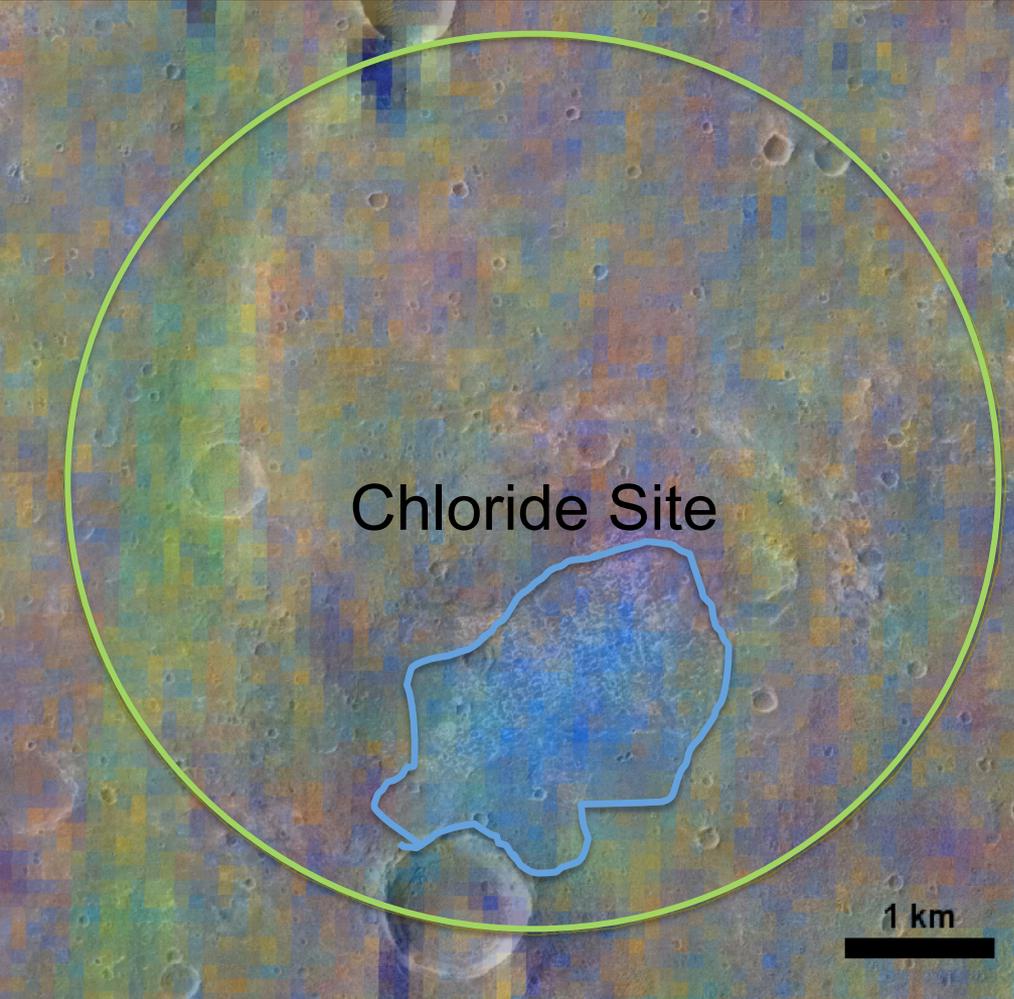
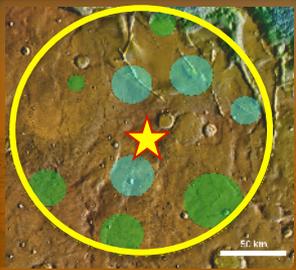
CTX basemap (NASA/JPL-Caltech/MSSS).

An astronaut in a white spacesuit stands on the reddish, rocky surface of Mars, looking out over a vast, flat landscape under a clear blue sky. A bright sun is visible on the horizon to the left. The astronaut is wearing a helmet and a backpack, and is standing with their back to the camera, looking towards the horizon.

RESOURCE ROI_s

Resource ROI 1

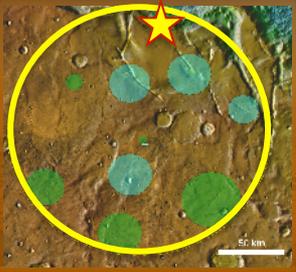
1st EZ Workshop for Human Missions to Mars



Coordinates: (-18.77°N, 310.65°E)
Elevation: 1,230m

- Coverage:
 - Full CTX/HRSC
 - No HiRISE/CRISM
- Available Resources:
 - Chloride Site
 - Building Material (dunes)

CTX basemap (NASA/JPL-Caltech/MSSS). Chloride site (THEMIS/Osterloo et al. 2008, 2010).



Resource ROI 2

1st EZ Workshop for Human Missions to Mars



RSL Activity

Coordinates: (-17.18°N, 310.90°E)
Elevation: 500m

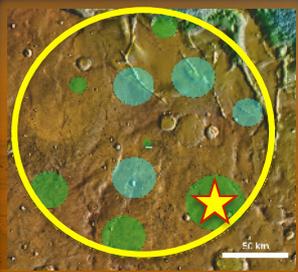
- Coverage:
 - Full CTX
 - Partial HRSC
 - No HiRISE/CRISM
- Available Resources:
 - Elevated ferric oxide and olivine throughout northern 75% of ROI (via OMEGA)
 - Proximity to active RSL in Valles Marineris

Opportunities for telerobotic ops

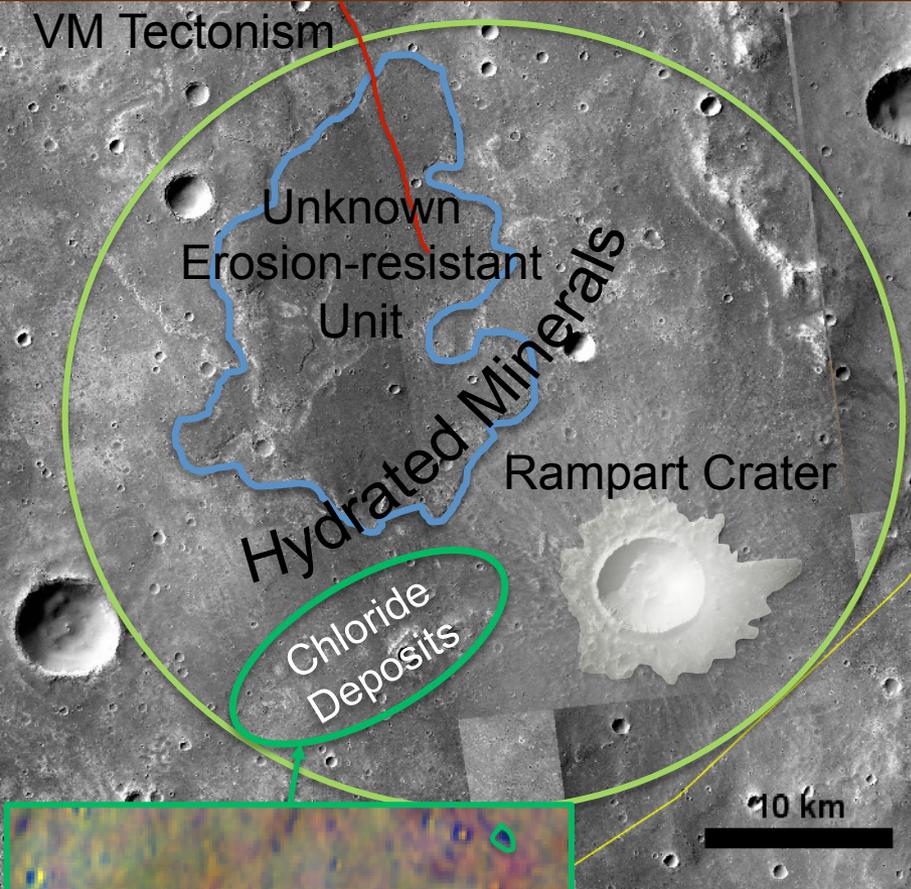
CTX basemap (NASA/JPL-Caltech/MSSS). Ferric oxide/olv - OMEGA (ESA/CNES/CNRS/IAS/ Université Paris-Sud, Orsay). HiRISE image (NASA/JPL/UA), RSL (McEwen et al., 2013).

Resource ROI 3

1st EZ Workshop for Human Missions to Mars



VM Tectonism



Coordinates: (-19.59°N, 311.58°E)
Elevation: 1,120m

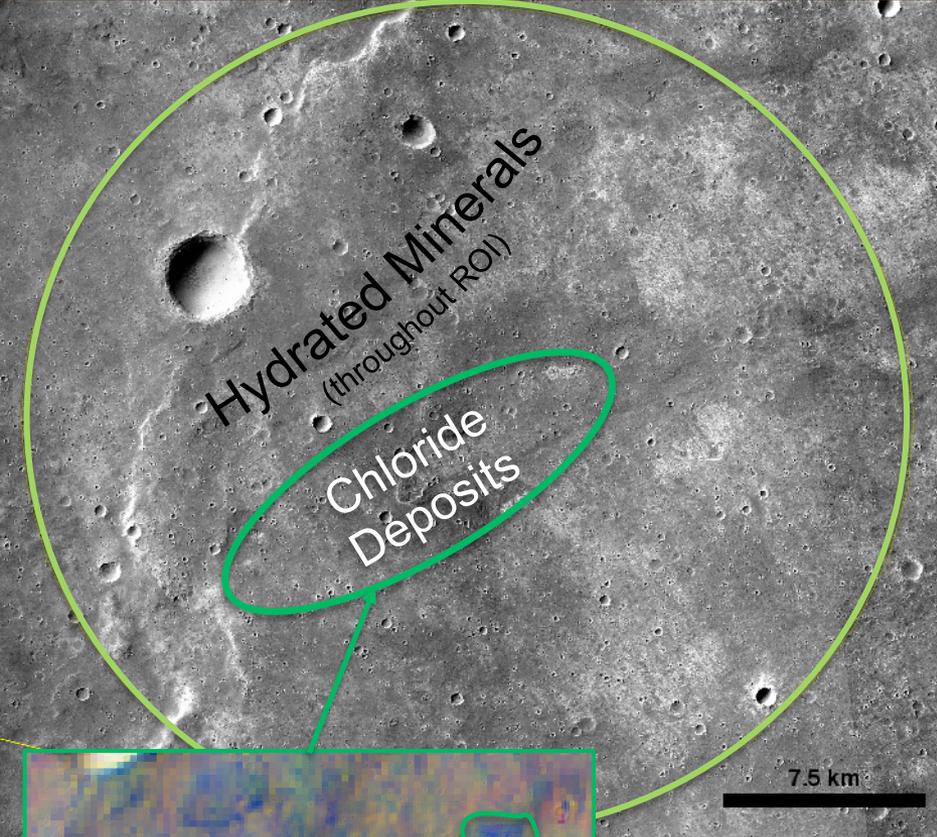
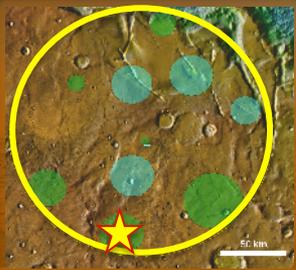
- Coverage:
 - Full CTX
 - Partial HRSC/CRISM
 - No HiRISE
- Available Resources:
 - Chloride deposits
 - Hydrated minerals throughout
 - Multiple science opportunities (erosion-resistant unit, rampart crater, tectonics)



MSSS). Hydrated
CNRS/IAS/ Université
EMIS/Osterloo et al.

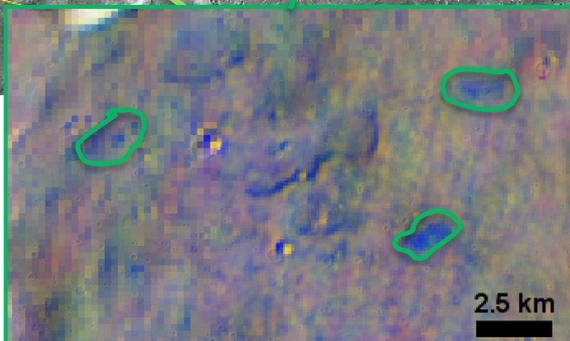
Resource ROI 4

1st EZ Workshop for Human Missions to Mars

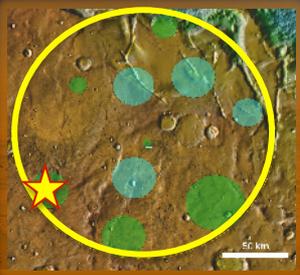


Coordinates: (-20.02°N, 310.30°E)
Elevation: 1,440m

- Coverage:
 - Full CTX/HRSC
 - Partial CRISM
 - No HiRISE
- Available Resources:
 - Chloride deposits
 - Hydrated minerals throughout ROI

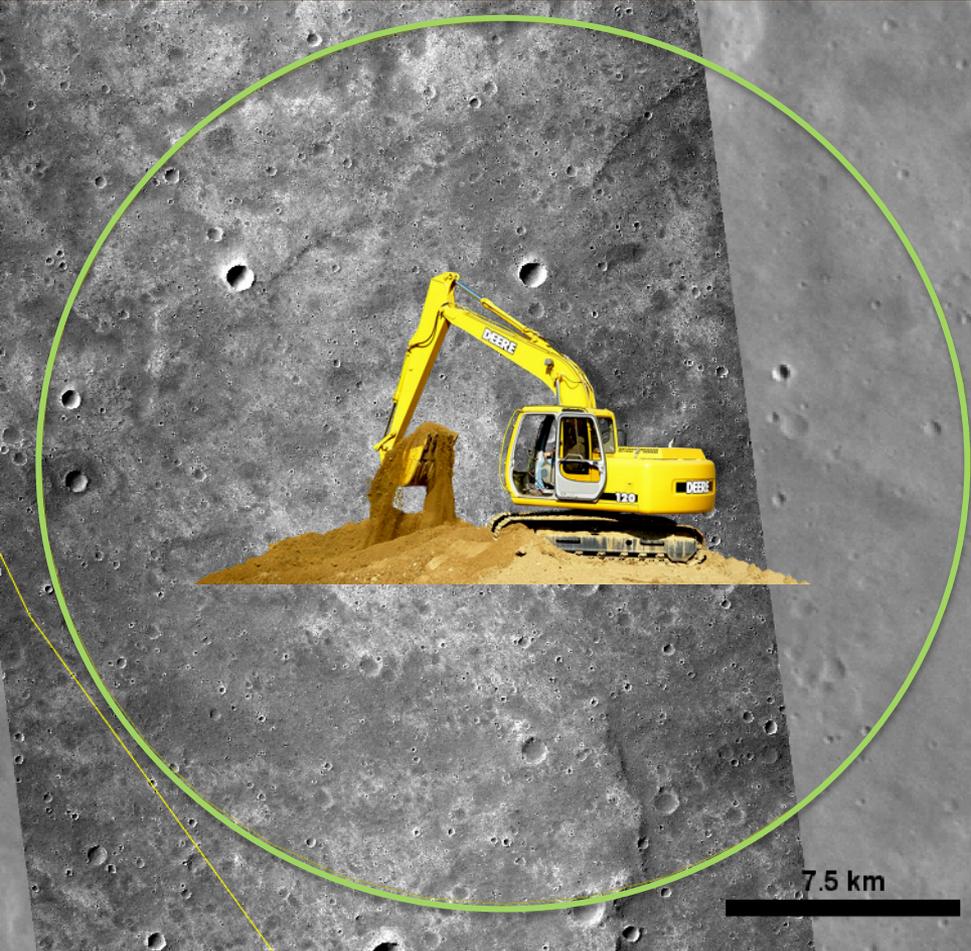


hydrated minerals from Paris-Sud, Orsay). (2010).



Resource ROI 5

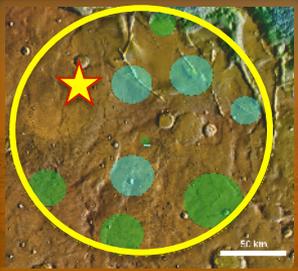
1st EZ Workshop for Human Missions to Mars



Coordinates: (-19.40°N, 309.27°E)
Elevation: 1,600m

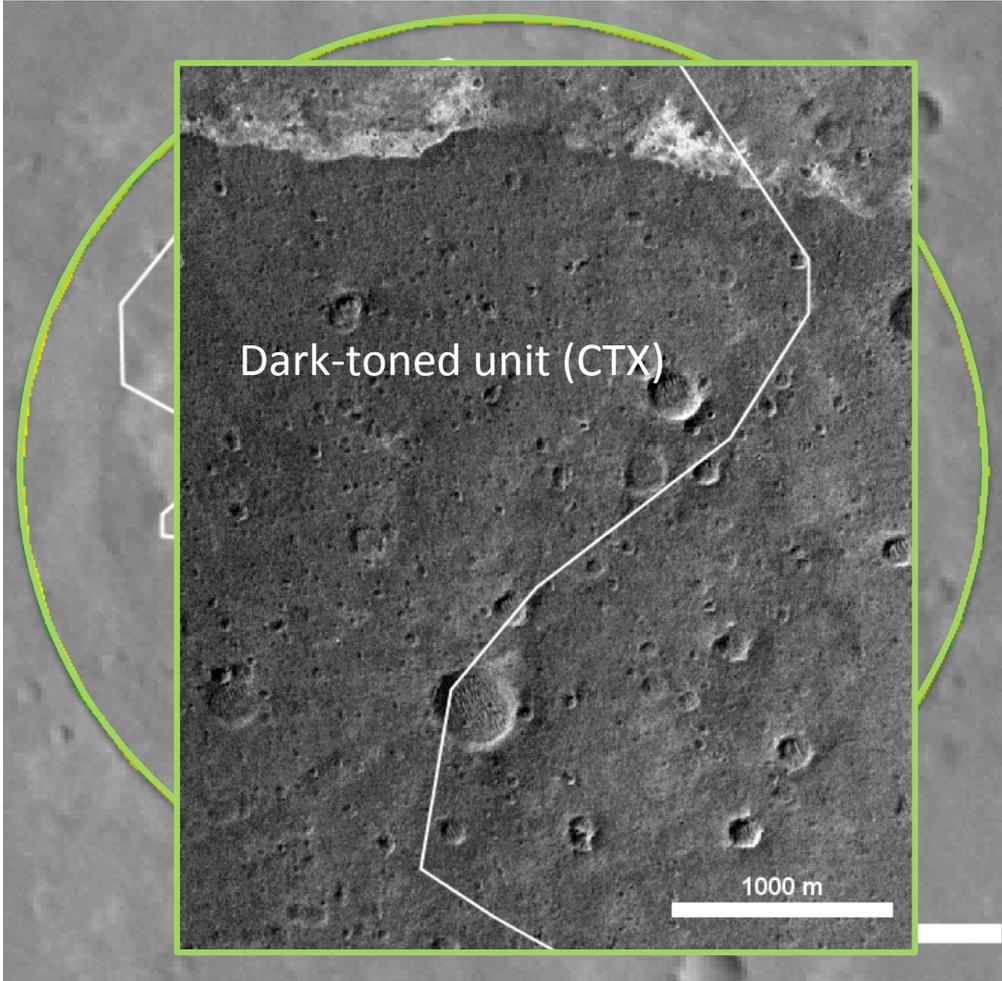
- Coverage:
 - Partial CTX/HRSC
 - No HiRISE/CRISM
- Available Resources:
 - Hydrated minerals throughout ROI
 - Abundant sand-sized grains (based on thermal inertia)
 - Possible plagioclase-rich and high-Si phases within ROI
 - Flat terrain

CTX basemap (NASA/JPL-Caltech/MSSS). Thermal inertia – THEMIS (NASA/JPL/ASU). Mineralogy – TES (NASA/JPL/ASU).



Resource ROI 6

1st EZ Workshop for Human Missions to Mars



Coordinates: (-17.98°N, 309.73°E)
Elevation: 1,192m

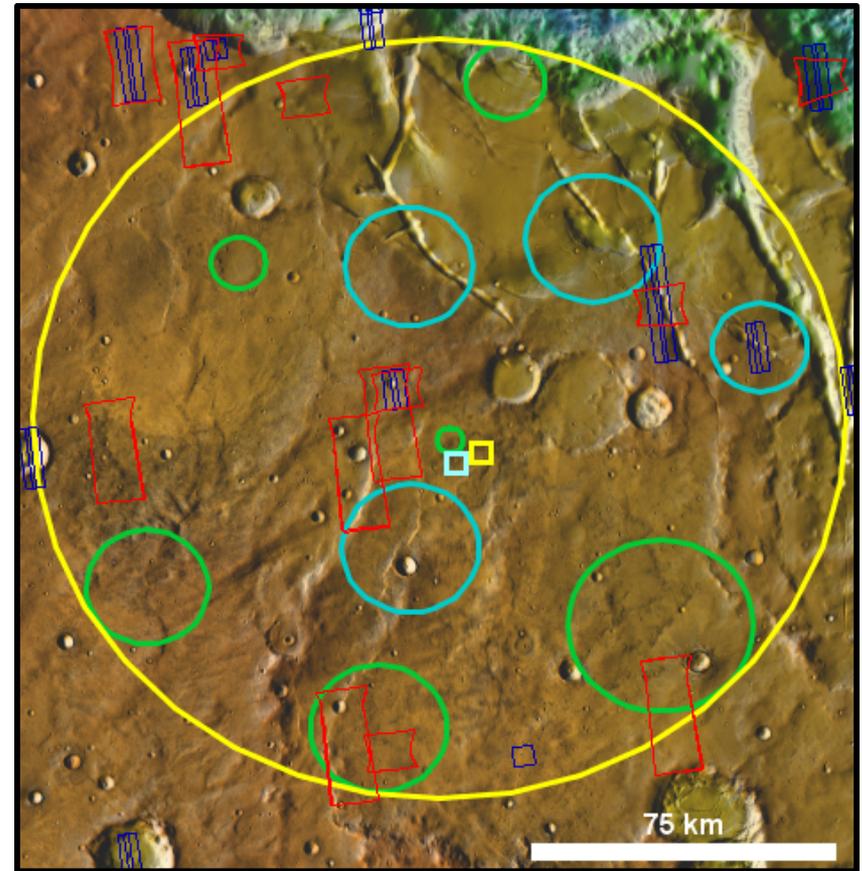
- Coverage:
 - Full CTX/HRSC
 - No HiRISE/CRISM
- Available Resources:
 - Olivine deposit in western ROI
 - Sand-sized basalt grains throughout ROI
 - Heavily degraded crater

CTX basemap (NASA/JPL4-Caltech/MSSS). Olivine and grain size (via thermal inertia) – THEMIS (NASA/JPL/ASU). Basalt – TES (NASA/JPL/ASU).

Highest Priority EZ Data Needs

1st EZ Workshop for Human Missions to Mars

1. Visible/near-infrared spectral verification of large-scale hydrated mineral deposits (CRISM FRT)
2. High-resolution imagery of landing and habitation sites (HiRISE)
3. High-spatial & spectral-resolution composition in thermal infrared (basalt, plagioclase, silica) and temperature
4. High-resolution slope for safety assessment of ROIs
5. Assessment of atmospheric water vapor



MOLA elevation (NASA/GSFC) on THEMIS Day IR (NASA/JPL/ASU).

BACK-UP SLIDES



Prioritization List of EZ Data Needs

1st EZ Workshop for Human Missions to Mars



- **Visible/near-IR spectroscopy of large-scale hydrated mineral deposits (CRISM FRT)**
 - Science: To assess the extent and duration of aqueous activity on the surface and to focus crew surface investigations.
 - Resource: To quantify the amount of water available and accessible for crew use.
- **High-spatial-resolution and high-spectral-resolution assessment of composition in thermal IR (basalt, plagioclase, silica) and characterization of temperatures in the region (diurnal/annual)**
 - Science: To characterize the geologic distribution of volcanics, sedimentary deposits, altered materials, and other minerals in the region. To characterize the thermal variation in the region with time of day and season.
 - Resource: To find minerals that harbor metals (Mg, Fe) and silica for building purposes. To assess crew safety and hardware requirements by understanding the thermal environment in which operations will be conducted.
- **High-resolution imagery of landing and habitation sites (HiRISE).**
 - Science: To assist with characterization of geologic and geomorphologic sites of interest.
 - Resource: To assess the boundaries of resources (i.e. dark-toned olivine deposits).
- **High-resolution slope for safety assessment of ROIs (HRSC).**
- **Assessment of atmospheric water vapor (MAVEN or other atmospheric science asset).**
 - Science: To characterize the atmospheric environment at the martian surface.
 - Resource: To quantify the abundance of water vapor to assess its potential as a water source for crew use during surface operations.
- **Rover-based exploration of chloride sites**
 - Science: To confirm the chloride anion present and assess ancient hydrologic environment
 - Resource: To explore small-scale adsorbed water, phyllosilicates, and possible liquid water at depth

Valles Marineris

1st EZ Workshop for Human Missions to Mars

